

## ROCK SOLE

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### EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 2000 SAFE:  
Changes to the input data

- 1) 2000 fishery age composition.
- 2) 2000 survey age composition.
- 3) 2001 trawl survey biomass point estimate and standard error.
- 4) Estimate of catch (t) and discards through 15, September 2001.
- 5) Estimate of retained and discarded portions of the 2000 catch.

### Assessment results

- 1) The projected age 2+ biomass for 2002 is 1,849,000 t.
- 2) The projected female spawning biomass for 2002 is 658,000 t.
- 3) The recommended 2002 ABC is 225,100 t based on an  $F_{40\%}$  (0.162) harvest level.
- 4) The 2002 overfishing level is 267,900 t based on an  $F_{35\%}$  (0.196) harvest level.

### Response to SSC Comments

The minutes from last December's Council meeting indicated that a computational error may have been made in the projection of  $F_{MAX\ ABC}$  since the projected values of female spawning biomass fell below the  $B_{35\%}$  level. Due to the low level of observed recruitment during the 1990s and the fact that rock sole do not become 50% mature until age 10, the future age composition of female spawning biomass will be at a level lower than  $B_{35\%}$  for a short time period (2008-2011 in this years projection) if harvested at this level, until the reservoir of spawners builds up again from the projected recruitment subsequent to the 1990s.

### SUMMARY

	2001 Assessment Recommendations for the 2002 harvest	2000 Assessment Recommendations for the 2001 harvest
Total biomass	1,849,000 t	1,938,600 t
ABC	225,100 t	227,700 t
Overfishing	267,900 t	270,700 t
$F_{ABC}$	$F_{0.40} = 0.162$	$F_{0.40} = 0.158$
$F_{overfishing}$	$F_{0.35} = 0.196$	$F_{0.35} = 0.191$

## INTRODUCTION

The northern rock sole (Lepidopsetta polyxystra n. sp.) is distributed primarily on the eastern Bering Sea continental shelf and in much lesser amounts in the Aleutian Islands region. Two species of rock sole are known to occur in the North Pacific ocean, a northern rock sole (L. polyxystra) and a southern rock sole (L. bilineata) (Orr and Matarese 2000). These species have an overlapping distribution in the Gulf of Alaska, but the northern species predominates the Bering Sea and Aleutian Islands populations where they are managed as a single stock.

Centers of abundance occur off the Kamchatka Peninsula (Shubnikov and Lisovenko 1964), British Columbia (Forrester and Thompson 1969), the central Gulf of Alaska, and in the southeastern Bering Sea (Alton and Sample 1975). Adults exhibit a benthic lifestyle and, in the eastern Bering Sea, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Northern rock sole spawn during the winter-early spring period of December-March.

## CATCH HISTORY

Rock sole catches increased from an average of 7,000 t annually from 1963-69 to 30,000 t between 1970 to 1975. Catches (t) since implementation of the MFCMA in 1977 are shown in Table 6.1, with catch data for 1980-88 separated into catches by non-U.S. fisheries; joint venture operations and DAP catches (where available). Prior to 1987, the classification of rock sole in the "other flatfish" management category prevented reliable estimates of DAP catch. Catches from 1987 - 2000 have averaged 54,960 t annually. The size composition of the 2000 catch from observer sampling, by sex and management area, are shown in Figure 6.1.

Rock sole are important as the target of a high value roe fishery occurring in February and March which accounts for the majority of the annual catch. The 2000 catch of 49,264 t was only 21% of the ABC of 230,000 t (36% of the TAC). The 2001 catch total is 28,000 t through September 15. Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands.

During the 2001 fishing season rock sole harvesting was periodically closed in the Bering Sea and Aleutian Islands due to bycatch restrictions, as follows:

<u>Area</u>	<u>Date</u>	<u>Bycatch closure</u>
BS/AI	3/6 - 4/1	First seasonal halibut cap
BS/AI	4/27 - 7/1	Second seasonal halibut cap
BS/AI	8/24 - 12/31	Annual halibut allowance

Although female rock sole are highly desirable when in spawning condition, large amounts of rock sole are discarded overboard in the various Bering Sea trawl target fisheries. Observer discard estimates applied to 'blend' estimates of observer sampling and industry reported catch provide the following estimates:

<u>Year</u>	<u>Retained</u>	<u>Discard</u>	<u>% Retained</u>
1987	14,209 t	14,701 t	49
1988	22,374 t	23,148 t	49
1989	23,544 t	24,358 t	49
1990	12,170 t	12,591 t	49
1991	25,406 t	35,181 t	42
1992	21,317 t	35,681 t	37
1993	22,589 t	45,669 t	33
1994	20,951 t	39,945 t	34
1995	21,761 t	33,108 t	40
1996	19,770 t	27,158 t	42
1997	27,743 t	39,821 t	41
1998	12,645 t	20,999 t	38
1999	15,224 t	25,286 t	38
2000	22,151 t	27,113 t	45

Since 1987 rock sole have been discarded in greater amounts than they have been retained. Fisheries with the highest discard rates include the rock sole roe fishery, the yellowfin sole, Pacific cod, and the bottom pollock fisheries. Since 1990, retention of rock sole has ranged from 33% in 1993 to 45% in 2000.

## DATA

The data used in this assessment include estimates of total catch, trawl fishery catch-at-age, trawl survey age composition, trawl survey biomass estimates and sampling error, maturity observations from observer sampling and mean weight-at-age.

### Fishery Catch and Catch-at-Age

Available information include fishery total catch data from 1975-September 15, 2001 (Table 6.1) and fishery catch-at-age numbers from 1980-2000 (Table 6.2).

### Survey CPUE

Since rock sole are lightly exploited and are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries are considered an unreliable method for detecting trends in abundance. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Abundance estimates from the 1982 AFSC survey were substantially higher than from the 1981 survey data for a number of bottom-tending species such as flatfishes. This is coincident with the change in research trawl to the 83/112 with better bottom tending characteristics. The increase in

survey CPUE was particularly large for rock sole (6.5 to 12.3 kg/ha, Figure 6.2). Consequently, CPUE and biomass from the 1975-81 surveys are not used in the assessment model.

The CPUE trend indicates a significantly increasing population from 1982-92 when the mean CPUE more than tripled. The population leveled-off from 1994-98 when CPUE values indicated a high level of abundance. The 1999 value of 36.5 kg/ha was the lowest observed since 1992, possibly due to extremely low water temperatures. In 2000 the CPUE increased to 45.92 and again in 2001 to 52.12

### Absolute Abundance

Estimates of rock sole biomass are also estimated from the AFSC surveys using stratified area-swept expansion of the CPUE data. The estimates are as follows:

Year	Eastern Bering Sea (t)	Aleutian Islands (t)
1975	175,500	
1979	194,700	
1980	283,800	28,500
1981	302,400	
1982	578,800	
1983	713,000	23,300
1984	799,300	
1985	700,100	
1986	1,031,400	26,900
1987	1,269,700	
1988	1,480,100	
1989	1,138,600	
1990	1,381,300	
1991	1,588,300	37,325
1992	1,543,900	
1993	2,123,500	
1994	2,894,200	54,785
1995	2,175,040	
1996	2,183,000	
1997	2,710,900	56,154
1998	2,168,700	
1999	1,689,100	
2000	2,127,700	45,949
2001	2,415,000	

It should be recognized that the biomass estimates given above are point estimates from an "area-swept" bottom trawl survey. As a result they are uncertain. It is assumed that the sampling plan covers the distribution of the fish and that all fish in the path of the footrope of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Due to sampling variability alone, the 95% confidence interval for the 2001 point estimate of the Bering Sea surveyed area is 1,868,000 t - 2,962,100 t.

Rock sole biomass was relatively stable through 1979, but then increased substantially in the following years to 799,300 t in 1984. In 1985 the estimate declined to 672,000 t but increased again in 1986 to over 1 million t and continued this trend through 1988. The 1989 and 1990 estimates were at a high and stable level (slightly less than the 1988 estimate) and continued to increase to the

highest level estimated by the trawl survey at 2.9 million metric tons in 1994. The 1995, 1996 and 1998 estimates are near the 1993 estimate of 2.2 million metric tons and the 1997 estimate is about the level of 1994. As described in a following section, past recruitment should contribute to a stable stock biomass in the near future.

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 1981 and 1982 indicate that the 83-112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-81. Allowing the stock assessment model to tune to these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. The pre-1982 survey biomass estimates were omitted from the analysis.

#### Weight-at-age and Maturity-at-age

In conjunction with the large and steady increase in the rock sole stock size since the early 1980s, it was found that there was also a corresponding decrease in size-at-age for both sexes (Figure 6.3). This also caused a resultant decrease in weight-at-age as the population increased and expanded westward toward the shelf edge (Walters and Wilderbuer 2000). These updated values of weight-at-age (Table 6.3) were used in this assessment to model the population dynamics of the rock sole population and were compared to results obtained from the constant growth model used in past assessments.

The length-weight relationship did not change significantly over this time period as discerned from an analysis of observations made in 1975, 1976 and 1988. The following parameters have been calculated for the length (cm)-weight (g) relationship:

$$W = a * L^{**b}$$

No significant differences were found between sexes so that these parameters are for both sexes combined.

<u>a</u>	<u>b</u>
0.007610	3.11976

Maturity information available from anatomical scans collected by fishery observers during the 1993 and 1994 Bering Sea rock sole roe fishery are used in this assessment (Table 6.4). These data indicate that the age of 50% maturity occurs at 9-10 years for female rock sole.

#### Survey and Fishery Age composition

Rock sole otoliths have routinely been collected during the trawl surveys since 1975 to provide estimates of the population age composition (appendix figures, Table 6.5). Age-length keys from

these surveys were applied to fishery size composition data from 1980-97 (prior to 1980 observer coverage was sparse and did not reflect the catch size composition) to provide a time-series of catch-at-age assuming that the mean length at age from the trawl survey was the same as the fishery in a given year. Estimation of the fishery age composition since 1997 used age structures collected annually from the fishery.

## ANALYTIC APPROACH

### Model Structure

The abundance, mortality, recruitment and selectivity of rock sole were assessed with a stock assessment model using the AD Model builder software. The conceptual model is similar to that implemented in the stock synthesis program (Methot 1990, Fournier and Archibald 1982). The model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information. The model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function.

The suite of parameters estimated by the model are classified by three likelihood components:

Data Component	Distribution assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 6-6). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the rock sole assessment except for the catch weight. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 6-6 presents the key equations used to model the rock sole population dynamics in the Bering Sea and Table 6-7 provides a description of the variables used in Table 6-6. The model of rock sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

### Parameters Estimated Independently

Most studies assume  $M = 0.20$  for rock sole on the basis of the longevity of the species. In a past assessment, the stock synthesis model was used to entertain a range of  $M$  values to evaluate the fit of the observable population characteristics over a range of natural mortality values (Wilderbuer and Walters 1992). The best fit occurred at  $M = 0.18$ , which is the value used in this assessment. The survey catchability coefficient ( $q$ ) was set equal to 1.0.

Rock sole maturity schedules were estimated as discussed in section 6.3.4 (Table 6.4).

#### Parameters Estimated Conditionally

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Total
27	4	46	77

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data and the entry of another year class into the observed population.

#### Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population using the population dynamics equations given in Table 6-6.

#### Selectivity

Fishery and survey selectivity were modeled in this assessment using the two parameter formulation of the double logistic function, as shown in Table 6-6. The model was configured with the selectivity curve fixed asymptotically for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years.

#### Fishing Mortality

The fishing mortality rates ( $F$ ) for each age and year are calculated to approximate the catch weight by solving for  $F$  while still allowing for observation error in catch measurement. A large emphasis (300) was placed on the catch likelihood component.

## MODEL RESULTS

### Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages and the estimated annual exploitation rates (catch/total biomass) are given Table 6.8. The exploitation rate has averaged just over 2% from 1975-2000, indicating a lightly exploited stock. Age-specific selectivity estimated by the model (Table 6.9, Fig. 6.4) indicate that rock sole are 50% selected by the fishery between the ages of 7 and 8 and are fully selected by age 12 (sexes combined).

### Abundance Trend

The stock assessment model indicates that rock sole total biomass was at low levels during the mid 1970s through 1982 (300,000 - 500,000 t, Fig. 6.4 and Table 6.10). From 1982-95, a period characterized by sustained above-average recruitment (1980-88 year classes, Fig. 6.4) and light exploitation, the estimated total biomass rapidly increased at a high rate to over 2.8 million t by 1995. Since then, the model indicates the population biomass has declined 30% to 1.99 million t in 2001 and is projected at 1,849,020 t for 2002. This decline is attributable to the below-average recruitment to the adult portion of the population during the 1990s. The female spawning biomass is estimated to be at a high and stable level of 703,500 t in 2001 (Table 6.10). The model provides good fits to most of the strong year classes observed in the fishery and surveys during the time-series. These are shown in the Appendix with the model estimates of population numbers at age.

The model estimates of survey biomass (using trawl survey age-specific selectivity applied to the total biomass, Fig. 6.4) corresponded fairly well with the trawl survey biomass trend through 1995. The 1999 survey point estimate is 200,000 t less than the model estimate and the 2000 and 2001 survey estimates are 200,000 and 600,000 t more than the model estimates. Both the trawl survey and the model indicate the same increasing biomass trend from the late 1970s to the mid 1990s and a present high level of abundance. The large variability in the survey biomass estimates during the last 5 years is not consistent with the observed age composition during this period and is not fit well by the model.

### Total Biomass

The stock assessment model estimates of total biomass (begin year population numbers multiplied by mid-year weight at age) is used to recommend the ABC for 2002. Including the 2001 catch of 28,000 t through 15 September (including discards), the model projects the total biomass for 2002 at **1,849,000 t**.

### Recruitment Trends

Increases in abundance described earlier for rock sole can be attributed to the recruitment of a series of strong year classes (Fig. 6.4 and 6.5, Table 6.11). Rock sole ages have now been read for samples obtained in 2000 and show the continuing presence of the 1986 and 1987 year classes (Fig. 6.5). The 1990 year class also appears strong, and as 10 year old fish in 2000, comprise a significant part

of the survey age composition numbers. The 1987 year class is the largest estimated during the recruitment time-series and still comprise 13% of the estimated 2000 survey age composition numbers as thirteen year old fish. Recruitment since 1990 has been below the 26 year average.

#### Spawner-Recruit Relationship

Model estimates of female spawning biomass and the relationship to estimated age 4 recruitment are shown in Figure 6.6. The twenty-one data points were fit with a Ricker (1958) form of spawner-recruit curve. However, estimation of MSY using these data is not recommended for management purposes since environmental processes which can determine the level of recruitment for a given stock size are not considered.

### ACCEPTABLE BIOLOGICAL CATCH

The reference fishing mortality rate for rock sole is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant  $F_{0.40}$  harvest to an estimate of average equilibrium recruitment. For the 2001 assessment, the Alaska Fisheries Science Center policy is to use only year classes spawned in 1977 or later to calculate the average equilibrium recruitment. Using the time-series of recruitment from 1978-2000 from the stock assessment model results in an estimate of  $B_{0.40} = 268,000$  t. The stock assessment model estimates the 2002 level of female spawning biomass at **658,000 t (B)**. Since reliable estimates of B,  $B_{0.40}$ ,  $F_{0.40}$ , and  $F_{0.30}$  exist and  $B > B_{0.40}$  ( $658,000 > 268,000$ , fig. 6.4), rock sole reference fishing mortality is defined in tier 3a. For the 2002 harvest:  $F_{ABC} \leq F_{0.40} = 0.162$  and  $F_{\text{overfishing}} = F_{0.35} = 0.196$  (full selection F values).

Acceptable biological catch is estimated for 2002 by applying the  $F_{0.40}$  fishing mortality rate and age-specific fishery selectivities to the 2002 estimate of age-specific total biomass as follows:

$$ABC = \sum_{a=a_r}^{a_{\max}} \bar{w}_a n_a \left( \frac{F S_a}{M + F S_a} \right) (1 - e^{-M - F S_a})$$

where  $S_a$  is the selectivity at age,  $M$  is natural mortality,  $\bar{w}_a$  is the mean weight at age from 1998, and  $n_a$  is the beginning of the year numbers at age. This results in a **2002 ABC of 225,100 t** for the eastern Bering Sea portion of the stock.

The stock assessment analysis must also consider harvest limits, usually described as “overfishing” fishing mortality levels with corresponding yield amounts. Previous stock assessments used  $F_{0.30}$  or

the fishing mortality rate which would reduce the spawning biomass per recruit to 30% of its unfished level as the harvest limit. Amendment 56 to the BS/AI FMP now sets the harvest limit at the  $F_{0.35}$  fishing mortality value. The overfishing fishing mortality value, ABC fishing mortality value and their corresponding yields are given as follows:

<u>Harvest level</u>	<u>F value</u>	<u>2002 Yield</u>
$F_{0.35}$	0.196	267,900 t
$F_{0.40}$	0.162	225,100 t

### BIOMASS PROJECTIONS

As in past years, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2001 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2002 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2001. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2002, are as follow (“ $\max F_{ABC}$ ” refers to the maximum permissible value of  $F_{ABC}$  under Amendment 56):

*Scenario 1:* In all future years,  $F$  is set equal to  $\max F_{ABC}$ . (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

*Scenario 2:* In all future years,  $F$  is set equal to a constant fraction of  $\max F_{ABC}$ , where this fraction is equal to the ratio of the  $F_{ABC}$  value for 2002 recommended in the assessment to the  $\max F_{ABC}$  for 2002. (Rationale: When  $F_{ABC}$  is set at a value below  $\max F_{ABC}$ , it is often set at the value recommended in the stock assessment.)

*Scenario 3:* In all future years,  $F$  is set equal to 50% of  $\max F_{ABC}$ . (Rationale: This scenario provides a likely lower bound on  $F_{ABC}$  that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

*Scenario 4:* In all future years,  $F$  is set equal to the 1997-2001 average  $F$ . (Rationale: For some stocks, TAC can be well below ABC, and recent average  $F$  may provide a better indicator of  $F_{TAC}$  than  $F_{ABC}$ .)

*Scenario 5:* In all future years,  $F$  is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as  $B_{35\%}$ ):

*Scenario 6:* In all future years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above  $\frac{1}{2}$  of its MSY level in 2002 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

*Scenario 7:* In 2002 and 2003,  $F$  is set equal to  $\max F_{ABC}$ , and in all subsequent years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 6.12 indicate that rock sole are currently not overfished and are not approaching an overfished condition. If harvested at the average  $F$  from 1997-2001, rock sole female spawning biomass is projected to decline over the next five years due to the reduced recruitment observed during the 1990s (fig. 6.7).

## OTHER CONSIDERATIONS

Trophic studies indicate that rock sole groundfish predators include Pacific cod, walleye pollock, skates, Pacific halibut and yellowfin sole, mostly on small rock sole ranging from 5 to 15 cm standard length. Rock sole diet includes bivalves, polychaetes, amphipods and miscellaneous crustaceans.

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Table 6.6--Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0, \delta_R^2)$	Recruitment 1956-75
$N_{t,1} = R_t = R_\gamma e^{\tau_t}, \quad \tau_t \sim N(0, \delta_R^2)$	Recruitment 1976-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}} (1 - e^{-Z_{t,a}}) N_{t,a}$	Catch in year $t$ for age $a$ fish
$N_{t+1,a+1} = N_{t,a} e^{-Z_{t,a}}$	Numbers of fish in year $t+1$ at age $a$
$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}}$	Numbers of fish in the “plus group”
$S_t = \sum N_{t,a} W_{t,a} \phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year $t$ at age $a$
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F_t}, \quad \varepsilon^F_t \sim N(0, \sigma^2_F)$	Fishing mortality
$s_a = \frac{1}{1 + (e^{-\alpha + \beta a})}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = C_{t,a} / C_t$	Proportion at age in catch
$SurB_t = q \sum N_{t,a} W_{t,a} v_a$	Survey biomass
$L = \sum_{t,a} m_t p_{t,a} \ln \frac{\hat{p}_{t,a}}{p_{t,a}} + (-0.5) \sum_t \left[ \left( \ln \frac{surB_t}{\hat{surB}_t} \right)^2 / \sigma_t^2 - \ln \sigma_t^2 \right]$	Total log likelihood

Table 6.7. Variables used in the population dynamics model.

## Variables

$R_t$	Age 1 recruitment in year $t$
$R_0$	Geometric mean value of age 1 recruitment, 1956-75
$R_\gamma$	Geometric mean value of age 1 recruitment, 1976-96
$\tau_t$	Recruitment deviation in year $t$
$N_{t,a}$	Number of fish in year $t$ at age $a$
$C_{t,a}$	Catch numbers of fish in year $t$ at age $a$
$P_{t,a}$	Proportion of the numbers of fish age $a$ in year $t$
$C_t$	Total catch numbers in year $t$
$W_{t,a}$	Mean body weight (kg) of fish age $a$ in year $t$
$\phi_a$	Proportion of mature females at age $a$
$F_{t,a}$	Instantaneous annual fishing mortality of age $a$ fish in year $t$
$M$	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age $a$ fish in year $t$
$s_a$	Age-specific fishing gear selectivity
$\mu^F$	Median year-effect of fishing mortality
$\varepsilon_t^F$	The residual year-effect of fishing mortality
$v_a$	Age-specific survey selectivity
$\alpha$	Slope parameter in the logistic selectivity equation
$\beta$	Age at 50% selectivity parameter in the logistic selectivity equation
$\sigma_t$	Standard error of the survey biomass in year $t$

## Appendix

- 1) Observed fishery trawl locations, by quarter, for the 2000 fishing season. Trawl locations where rock sole comprised 20% or more of the catch are identified by darker circles.
- 2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).
- 3) Table of the assessment model estimates of population numbers at age 1975- 2001.
- 4) Table of total population removals of rock sole from Alaska Fisheries Science Center research activities, 1977-95.

Table 6.1--Rock sole catch from 1977 - September 15, 2001

Year	Foreign	Joint-Venture	Domestic	Total
1977	5,319			5,319
1978	7,038			7,038
1979	5,874			5,874
1980	6,329	2,469		8,798
1981	3,480	5,541		9,021
1982	3,169	8,674		11,844
1983	4,479	9,140		13,618
1984	10,156	27,523		18,750
1985	6,671	12,079		37,678
1986	3,394	16,217		23,483
1987	776	11,136	28,910	40,046
1988		40,844	45,522	86,366
1989		21,010	47,902	68,912
1990		10,492	24,761	35,253
1991			60,587	60,587
1992			56,998	56,998
1993			63,953	63,953
1994			60,544	60,544
1995			58,870	58,870
1996			46,928	46,928
1997			67,564	67,564
1998			33,645	33,645
1999			40,510	40,510
2000			49,264	49,264
2001			27,995	27,995

Table 6.2--Estimated catch numbers at age, 1980-2000.

year/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0	0	1,506,280	1,287,139	3,813,569	2,191,411	2,219,119	1,627,186	1,544,063	4,057,889	2,521,382	1,332,479	1,050,366	1,012,563	664,980	168,764	50,377	0	0	0
1981	0	0	1,613,369	2,674,062	1,526,839	8,407,384	1,764,098	881,345	1,144,431	1,539,464	3,212,782	1,431,935	1,236,544	1,636,416	887,632	516,390	136,774	27,913	0	0
1982	0	0	1,612,930	2,305,370	2,235,614	5,006,769	8,964,406	5,568,947	2,234,862	2,404,682	2,761,468	3,203,274	2,726,298	2,492,666	1,283,537	352,440	132,663	0	41,463	0
1983	0	0	0	3,517	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	1,565,446	0
1984	0	0	0	0	2,840,068	6,868,823	5,574,313	11,672,164	15,210,756	9,937,980	5,906,410	5,692,916	8,546,267	6,187,083	5,603,964	4,566,309	1,284,856	165,300	52,150	0
1985	0	1,469,731	3,286,253	11,807,393	20,807,434	12,839,608	8,141,321	6,531,222	4,136,716	5,961,495	1,023,868	412,846	322,020	726,609	2,311,937	1,403,676	528,443	140,368	978,470	322,020
1986	0	0	0	498,195	8,076,521	17,613,373	13,113,171	7,927,508	9,156,868	2,831,253	8,829,039	1,154,863	1,139,952	976,037	350,181	901,531	946,235	29,803	0	312,928
1987	0	0	0	2,071,165	7,894,882	13,481,676	23,226,085	6,993,046	5,777,861	4,501,535	2,392,157	6,458,059	993,548	267,494	351,563	191,067	672,555	343,920	84,069	718,411
1988	0	0	572,874	1,201,187	34,686,579	25,797,797	33,965,867	21,843,120	12,972,818	30,768,862	6,153,772	4,767,788	3,936,197	3,012,207	0	628,313	554,394	2,531,732	406,556	997,909
1989	0	0	0	1,456,365	10,113,391	33,265,317	16,029,266	21,433,568	10,454,439	10,231,446	8,696,729	5,141,968	4,106,686	5,286,247	2,925,144	1,154,317	131,172	0	0	695,214
1990	0	0	0	232,509	2,893,518	7,159,894	17,827,931	8,069,413	10,544,945	8,780,615	3,266,150	1,422,405	1,901,089	868,488	2,400,308	1,135,189	253,024	266,701	102,577	1,210,412
1991	0	17,748	2,200,775	7,609,201	4,670,157	12,352,736	17,268,982	41,193,533	28,627,820	19,895,713	15,884,624	8,181,913	3,727,118	3,514,140	3,345,533	3,673,874	1,135,884	727,676	0	1,738,322
1992	0	0	189,534	1,016,593	9,166,571	9,269,954	14,680,299	35,425,697	32,599,912	14,008,313	23,123,194	11,766,382	4,634,977	5,562,649	2,532,868	223,965	6,254,634	568,603	534,142	708,446
1993	0	0	0	0	0	2,874,853	11,020,196	20,443,259	13,895,028	60,531,213	9,742,491	15,811,583	12,138,185	3,353,972	3,353,972	1,766,843	782,594	1,277,704	1,597,130	798,565
1994	0	0	0	233,760	0	2,669,176	16,645,048	29,410,872	28,034,637	28,530,944	27,862,271	16,482,285	9,965,929	8,168,894	3,289,168	2,656,019	746,043	116,051	1,193,669	0
1995	0	0	0	323,358	1,168,369	1,168,369	1,168,369	23,463,011	17,624,400	17,624,400	18,862,271	16,482,285	9,965,929	8,168,894	3,289,168	2,656,019	746,043	116,051	1,193,669	0
1996	0	0	0	48,548	1,195,726	3,986,294	9,556,430	3,462,715	27,420,956	22,641,681	18,862,271	16,482,285	9,965,929	8,168,894	3,289,168	2,656,019	746,043	116,051	1,193,669	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	9,110	126,420	1,849,142	1,849,145	3,650,123	20,447,914	4,834,055	21,822,446	55,934,413	25,705,375	21,733,179	16,696,384	12,100,188	6,794,697	3,583,803	2,036,765	1,344,465	236,084	236,102
1999	0	0	0	0	0	338,028	1,215,152	5,109,059	4,450,470	10,219,883	31,960,921	15,825,800	6,706,377	6,525,209	2,551,910	1,181,298	1,654,521	1,144,672	112,498	82,239
2000	0	0	0	0	1,235,298	1,184,694	3,084,841	1,773,845	13,337,355	6,468,742	13,330,158	38,865,511	12,458,145	6,245,110	6,608,513	1,238,843	373,651	496,890	1,003,786	157,914
	0	0	0	0	304,454	969,883	1,873,115	3,299,495	8,431,380	26,140,003	9,286,106	11,978,664	32,324,119	13,048,929	6,886,844	4,048,215	2,564,085	496,978	0	0

Table 6-3 --Rock sole weight-at-age (grams) by age and year determined from 1980-2000 from length-at-age and length-weight relationships from the annual trawl survey in the eastern Bering Sea.

year/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0	6	31	76	135	202	274	344	409	471	523	572	613	646	677	703	727	745	764	777
1981	0	6	31	76	135	202	274	344	409	471	523	572	613	646	677	703	727	745	764	777
1982	0	18	56	87	106	164	215	271	338	395	466	415	522	544	725	763	742	742	742	742
1983	0	17	35	109	160	195	261	296	357	369	480	406	513	531	588	655	835	948	865	865
1984	0	19	30	64	141	187	248	306	365	424	480	450	496	628	466	588	727	727	727	727
1985	0	16	32	54	113	197	264	325	363	469	468	650	556	477	654	595	556	604	785	807
1986	0	19	32	46	110	198	307	346	383	431	475	483	541	502	616	693	652	795	795	795
1987	0	15	36	74	120	212	331	447	450	421	498	522	543	612	486	682	701	746	696	696
1988	0	17	29	55	127	202	302	400	415	520	524	565	508	615	611	679	643	659	654	654
1989	0	16	27	58	106	184	246	373	439	518	521	515	511	605	594	566	703	703	682	703
1990	0	9	17	41	83	151	243	345	409	473	524	559	536	609	648	755	755	743	743	743
1991	0	13	17	36	77	126	198	296	345	432	493	541	603	611	690	751	751	696	622	688
1992	0	10	18	39	64	105	188	239	320	382	429	488	527	537	565	596	709	709	709	709
1993	0	9	24	38	85	114	184	220	314	399	496	547	565	564	609	661	661	661	739	739
1994	0	12	26	50	79	111	176	233	302	378	407	484	512	574	538	599	791	700	644	644
1995	0	12	26	43	79	123	172	236	289	418	442	500	720	706	672	833	833	752	752	790
1996	0	8	24	55	80	135	180	250	271	327	418	454	434	551	514	610	705	659	770	722
1997	0	8	23	49	86	120	178	223	250	318	363	382	443	513	577	529	546	695	695	695
1998	0	8	23	49	86	120	178	223	250	318	363	382	443	513	577	529	546	695	695	695
1999	0	8	23	49	86	120	178	223	250	318	363	382	443	513	577	529	546	695	695	695
2000	0	8	23	49	86	120	178	223	250	318	363	382	443	513	577	529	546	695	695	695

Table 6-4.--Mean length-at-age (cm) and proportion mature for female Bering Sea rock sole from observer anatomical scans during the 1993-94 fishing seasons.

Age	Length-at-age	Proportion mature
1	4.0	0
2	8.2	0.006
3	14.3	0.003
4	19.4	0.012
5	23.6	0.039
6	27.1	0.098
7	30.1	0.198
8	32.6	0.330
9	34.6	0.470
10	36.4	0.590
11	37.8	0.680
12	39.0	0.746
13	40.0	0.795
14	40.8	0.830
15	41.5	0.856
16	42.1	0.875
17	42.6	0.889
18	43.0	0.900
19	43.4	0.908
20	43.7	0.915

Table 6.5--Estimated population numbers-at-age from the annual Bering Sea trawl surveys, 1982- 2000.

year	1	2	3	4	5	6	7	8	9	10
1982	0	225,915,871	253,410,032	491,251,081	536,301,753	526,695,360	530,339,164	245,459,913	83,476,246	73,538,597
1983	0	70,146,087	667,990,146	552,979,049	632,739,066	312,630,782	312,630,782	353,935,077	161,656,464	135,663,244
1984	0	155,455,109	468,530,441	1,058,307,206	666,421,763	367,203,155	588,044,675	258,081,463	323,467,873	128,174,686
1985	0	164,995,571	412,930,092	1,128,940,284	1,127,616,790	523,221,249	327,726,685	247,052,192	141,172,681	157,936,937
1986	0	117,330,676	596,380,276	1,299,148,471	1,384,258,806	1,214,038,136	532,547,525	287,551,346	276,608,589	53,497,925
1987	0	64,442,126	751,624,053	1,073,834,685	1,148,515,280	901,587,506	1,030,471,759	268,609,237	268,609,237	171,644,916
1988	0	335,346,670	1,104,051,960	1,467,749,194	1,931,078,410	974,449,382	504,640,037	306,996,106	306,996,106	66,421,321
1989	0	130,635,572	866,884,259	969,480,719	1,136,194,516	1,304,345,945	748,977,281	414,014,275	414,014,275	128,625,794
1990	0	2,985,011,041	4,732,599,323	2,496,554,689	1,352,171,235	1,649,897,012	490,007,007	689,882,997	457,443,250	190,730,576
1991	0	26,889,987	167,793,518	3,633,375,028	2,308,236,475	1,338,045,748	973,417,525	847,572,387	505,633,289	354,947,827
1992	0	8,717,815	244,098,829	657,710,734	2,945,652,934	2,283,098,969	867,906,948	1,056,792,947	505,633,289	300,280,306
1993	0	45,456,620	994,850,590	1,384,478,759	1,250,706,421	3,957,323,432	2,180,618,983	1,019,527,041	958,485,295	540,284,394
1994	0	43,414,950	507,798,502	2,183,503,189	1,356,356,526	1,365,164,035	4,533,134,237	2,238,840,881	1,075,275,477	348,200,349
1995	0	0	139,718,785	850,148,391	1,845,692,845	847,646,539	727,172,766	2,228,283,677	1,255,342,489	507,827,746
1996	0	38,289,799	955,910,314	434,702,415	687,397,292	1,832,136,719	539,349,335	901,337,711	2,132,582,623	1,269,781,869
1997	0	4,207,952	572,689,014	1,528,289,628	552,308,622	903,690,557	2,558,218,730	523,296,535	948,287,650	2,040,952,394
1998	0	1,661,532	233,739,495	653,864,818	762,747,096	532,122,974	833,812,210	1,607,399,938	494,998,115	525,199,924
1999	0	651,774	63,705,533	105,156,287	294,735,960	834,758,997	115,842,503	621,721,866	1,469,603,868	829,476,619
2000	0	0	41,099,228	503,340,808	236,839,758	376,773,577	871,709,621	357,913,147	959,715,408	1,416,078,967
year	11	12	13	14	15	16	17	18	19	20
1982	61,944,674	108,982,876	61,944,674	24,512,866	5,962,589	7,950,119	7,950,119	0	993,765	0
1983	53,054,654	72,282,516	98,631,807	51,630,368	35,963,222	24,212,862	4,272,858	2,136,429	712,143	0
1984	52,395,733	57,158,982	64,953,388	38,539,010	51,096,665	22,950,197	8,660,452	0	2,165,113	3,031,158
1985	35,734,335	15,440,762	7,058,634	16,764,256	44,116,463	36,616,664	8,382,128	8,382,128	2,205,823	2,205,823
1986	201,833,080	21,277,584	21,277,584	21,277,584	0	21,277,584	21,277,584	0	0	10,942,757
1987	75,282,858	215,007,842	31,919,932	10,840,732	10,840,732	0	0	0	0	0
1988	163,623,255	88,291,756	69,661,386	57,511,144	0	6,480,129	11,340,226	58,321,160	23,490,487	8,100,161
1989	92,449,790	93,789,642	68,332,453	81,061,047	26,127,114	24,117,336	2,009,778	2,009,778	16,748,150	14,738,372
1990	83,735,375	94,589,960	24,810,481	58,924,893	1,550,655	0	10,864,586	0	37,215,722	0
1991	229,102,688	150,583,927	70,989,565	55,931,173	33,343,584	13,982,793	0	44,099,578	0	0
1992	298,343,013	185,011,414	130,767,230	91,052,738	45,526,369	25,184,800	12,592,400	0	10,655,108	0
1993	161,046,310	149,357,465	146,759,943	97,407,042	48,054,141	10,390,084	0	0	5,195,042	10,390,084
1994	663,904,023	295,355,289	167,494,542	190,424,438	89,897,342	54,971,010	13,514,972	10,629,753	28,852,188	16,096,484
1995	462,197,823	392,829,178	111,380,505	134,445,652	92,164,361	3,233,162	8,766,480	1,924,501	2,213,176	10,026,651
1996	368,987,906	190,796,495	230,727,427	69,085,751	97,479,323	85,348,782	31,537,428	10,874,975	1,384,088	8,759,298
1997	783,446,244	577,844,055	373,045,092	280,805,836	118,733,766	124,919,814	55,027,058	28,772,318	0	13,894,632
1998	1,426,269,570	922,756,102	304,441,149	107,739,974	133,701,414	45,778,672	29,422,965	8,039,392	11,223,996	18,692,237
1999	584,015,860	1,375,611,846	528,636,567	237,861,983	112,063,969	122,804,658	26,752,509	26,752,509	11,203,158	1,727,951
2000	741,155,198	639,002,427	1,054,480,737	442,237,063	240,273,363	207,076,253	59,972,490	8,832,372	11,512,553	14,100,193



Table 6.8--Model estimates of rock sole  
fishing mortality and exploitation rate  
(catch/total biomass).

<b>year</b>	<b>Full selection</b>	<b>Exploitation ra</b>
1975	0.109	0.046
1976	0.080	0.036
1977	0.037	0.018
1978	0.043	0.021
1979	0.032	0.016
1980	0.045	0.021
1981	0.043	0.019
1982	0.061	0.022
1983	0.059	0.020
1984	0.148	0.050
1985	0.061	0.021
1986	0.063	0.021
1987	0.051	0.017
1988	0.102	0.036
1989	0.060	0.023
1990	0.028	0.012
1991	0.062	0.029
1992	0.055	0.027
1993	0.051	0.026
1994	0.042	0.023
1995	0.031	0.019
1996	0.028	0.018
1997	0.040	0.028
1998	0.020	0.014
1999	0.024	0.018
2000	0.030	0.023

**Table 6.9. --Model estimates of rock sole age-specific fishery and survey selectivities.**

<b>Age</b>	<b>Fishery (1980-2000)</b>	<b>Survey (1982-2000)</b>
1	0	0.01
2	0	0.06
3	0.01	0.29
4	0.03	0.71
5	0.07	0.94
6	0.16	0.99
7	0.32	1.0
8	0.54	1.0
9	0.75	1.0
10	0.88	1.0
11	0.95	1.0
12	0.98	1.0
13	0.99	1.0
14	0.99	1.0
15	0.99	1.0
16	0.99	1.0
17	0.99	1.0
18	0.99	1.0
19	0.99	1.0
20	0.99	1.0

**Table 6-10.--Model estimates of rock sole age 2+ total biomass and female spawning biomass from the 2000 and 2001 assessments.**

	<b>2000 Assessment</b>		<b>2001 Assessment</b>	
	<b>Age 2+</b>	<b>Female</b>	<b>Age 2+</b>	<b>Female</b>
	<b>Total biomass</b>	<b>Spawning biomass</b>	<b>Total biomass</b>	<b>Spawning biomass</b>
<b>1975</b>	272,685	46,082	262,083	44,366
<b>1976</b>	288,468	51,455	276,887	49,325
<b>1977</b>	308,040	58,574	295,715	56,003
<b>1978</b>	340,589	67,302	327,629	64,320
<b>1979</b>	379,908	74,714	366,409	71,390
<b>1980</b>	429,879	81,700	415,933	78,134
<b>1981</b>	488,048	88,209	473,743	84,474
<b>1982</b>	541,361	82,894	528,189	79,525
<b>1983</b>	697,116	95,358	682,587	91,792
<b>1984</b>	772,910	108,584	758,147	104,961
<b>1985</b>	918,914	124,756	902,719	120,817
<b>1986</b>	1,147,650	149,328	1,130,540	145,222
<b>1987</b>	1,558,430	197,413	1,539,320	192,997
<b>1988</b>	1,783,800	243,660	1,766,260	239,018
<b>1989</b>	1,982,210	285,667	1,971,280	280,634
<b>1990</b>	2,009,130	338,602	2,000,450	333,143
<b>1991</b>	2,107,600	384,839	2,108,930	379,606
<b>1992</b>	2,110,160	403,192	2,124,480	398,891
<b>1993</b>	2,445,880	497,951	2,478,230	494,777
<b>1994</b>	2,509,460	542,961	2,562,010	542,979
<b>1995</b>	2,760,150	688,625	2,824,940	691,940
<b>1996</b>	2,531,340	658,827	2,612,070	667,967
<b>1997</b>	2,357,140	668,920	2,439,030	682,831
<b>1998</b>	2,259,960	688,769	2,343,820	707,962
<b>1999</b>	2,129,500	690,477	2,207,950	713,694
<b>2000</b>	2,040,660	690,719	2,110,030	717,272
<b>2001</b>			1,991,090	703,513

**Table 6.11--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2000 and 2001 assessments.**

<b>Year class</b>	<b>2000 Assessment</b>	<b>2001 Assessment</b>
<b>1971</b>	176,871	170,466
<b>1972</b>	144,681	140,300
<b>1973</b>	191,329	186,424
<b>1974</b>	258,211	252,513
<b>1975</b>	672,278	659,713
<b>1976</b>	376,587	370,683
<b>1977</b>	565,214	557,733
<b>1978</b>	644,766	637,734
<b>1979</b>	821,818	813,656
<b>1980</b>	1,600,780	1,583,760
<b>1981</b>	1,629,900	1,615,740
<b>1982</b>	1,445,070	1,427,640
<b>1983</b>	2,602,380	2,579,960
<b>1984</b>	2,057,360	2,063,200
<b>1985</b>	2,045,830	2,071,640
<b>1986</b>	3,178,810	3,235,900
<b>1987</b>	5,258,070	5,458,160
<b>1988</b>	1,832,260	1,928,850
<b>1989</b>	1,133,870	1,252,370
<b>1990</b>	2,499,560	2,752,100
<b>1991</b>	955,422	1,098,120
<b>1992</b>	524,740	547,732
<b>1993</b>	1,236,920	1,203,400
<b>1994</b>	678,151	616,082
<b>1995</b>	330,370	300,570

**Table 6.12--Projections of rock sole female spawning biomass (1,000s t), future catch (1,000s t) and full selection fishing mortality rates for seven future harvest scenarios.**

**Scenarios 1 and 2**

**Maximum ABC harvest permissible**

Year	Female spawning	catch	F
2001	692.068	27.995	0.02
2002	650.210	225.121	0.16
2003	525.555	179.887	0.16
2004	432.113	146.564	0.16
2005	359.901	121.600	0.16
2006	293.587	100.416	0.16
2007	250.162	82.079	0.15
2008	230.259	72.195	0.14
2009	221.744	69.859	0.13
2010	222.854	72.804	0.13
2011	230.787	78.799	0.14
2012	239.500	84.420	0.14
2013	247.997	89.395	0.14
2014	255.952	93.662	0.15

**Scenario 3**

**1/2 Maximum ABC harvest permissible**

Year	Female spawning	catch	F
2001	692.068	27.995	0.02
2002	654.452	116.768	0.08
2003	571.027	100.605	0.08
2004	505.841	88.137	0.08
2005	452.251	78.211	0.08
2006	392.068	68.145	0.08
2007	349.282	61.695	0.08
2008	326.812	59.170	0.08
2009	310.783	58.045	0.08
2010	304.914	58.371	0.08
2011	309.215	59.934	0.08
2012	316.241	61.743	0.08
2013	325.237	63.755	0.08
2014	335.724	65.868	0.08

**Scenario 4**

**Harvest at average F over the past 5 years**

Year	Female spawning	catch	F
2001	692.068	27.995	0.02
2002	657.224	41.842	0.03
2003	602.729	37.866	0.03
2004	560.625	34.794	0.03
2005	525.333	32.299	0.03
2006	474.906	29.236	0.03
2007	437.840	27.235	0.03
2008	420.010	26.592	0.03
2009	404.504	26.238	0.03
2010	398.598	26.445	0.03
2011	404.577	27.275	0.03
2012	413.091	28.137	0.03
2013	424.340	29.042	0.03
2014	438.226	30.019	0.03

**Scenario 5**

**No fishing**

Year	Female spawning	catch	F
2001	692.068	0	0
2002	658.721	0	0
2003	620.521	0	0
2004	592.583	0	0
2005	569.633	0	0
2006	527.033	0	0
2007	495.606	0	0
2008	482.899	0	0
2009	469.671	0	0
2010	465.402	0	0
2011	474.003	0	0
2012	484.774	0	0
2013	498.628	0	0
2014	515.797	0	0

**Table 6.12--continued.**

**Scenario 6**

**Determination of whether rock sole are currently overfished B35=234.54**

Year	Female spawning	catch	F
2001	692.068	27.995	0.02
2002	648.453	267.889	0.20
2003	507.736	207.473	0.20
2004	404.783	164.062	0.20
2005	327.519	132.471	0.20
2006	260.984	104.471	0.19
2007	220.217	76.871	0.16
2008	205.263	69.634	0.15
2009	200.875	69.919	0.14
2010	204.728	75.156	0.15
2011	213.917	83.234	0.15
2012	222.964	90.298	0.16
2013	231.018	96.163	0.16
2014	237.944	100.789	0.17

**Scenario 7**

**Determination of whether rock sole are at an overfished condition B35=234.54**

Year	Female spawning	catch	F
2001	692.068	27.995	0.02
2002	650.210	225.121	0.16
2003	525.555	179.887	0.16
2004	430.944	174.412	0.20
2005	347.793	140.353	0.20
2006	275.720	112.898	0.20
2007	229.931	83.436	0.17
2008	211.430	73.540	0.15
2009	204.635	72.221	0.15
2010	206.914	76.463	0.15
2011	215.112	83.911	0.15
2012	223.519	90.575	0.16
2013	231.196	96.217	0.16
2014	237.924	100.736	0.17

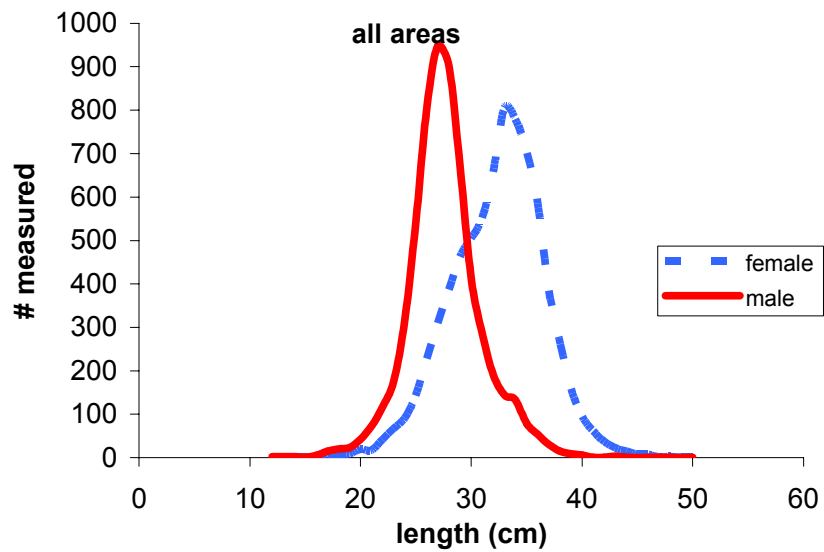
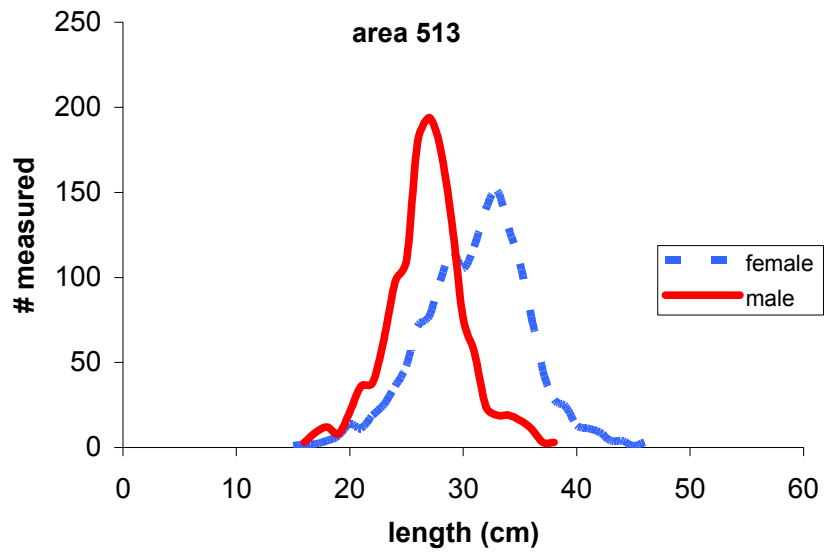


Figure 6.1--Size composition of the rock sole catch in 2000 determined from observer sampling of the commercial catch.

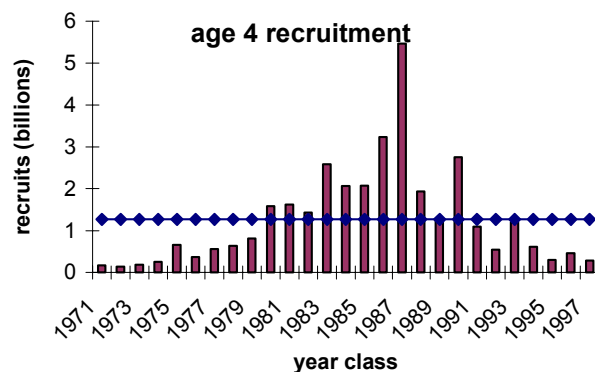
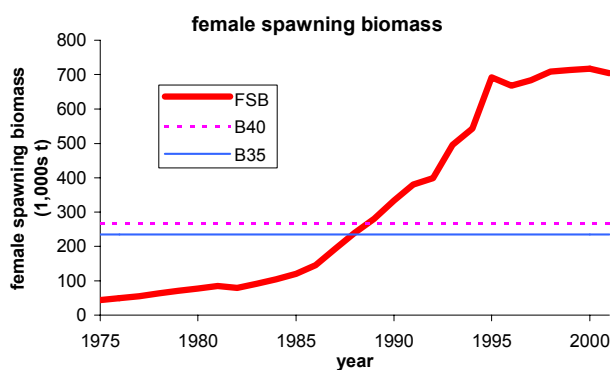
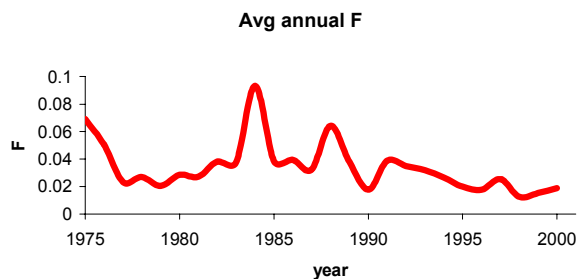
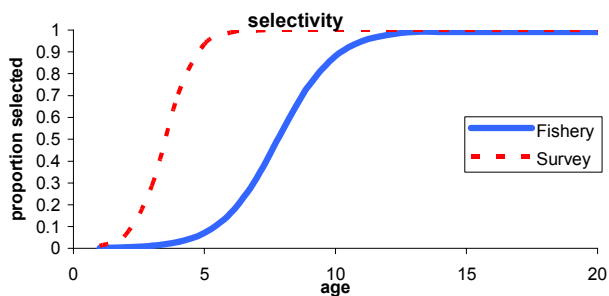
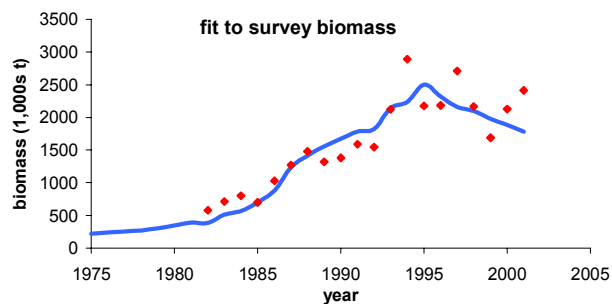
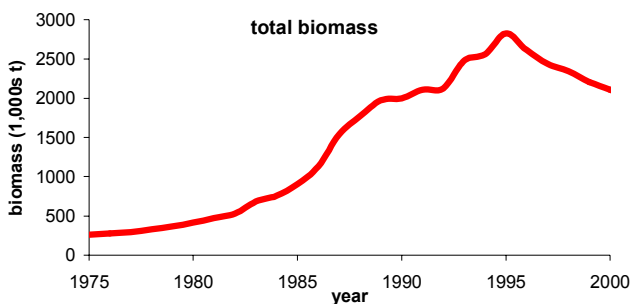


Figure 6.4--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom right panel) and estimated age 4 recruitment (bottom right panel)..

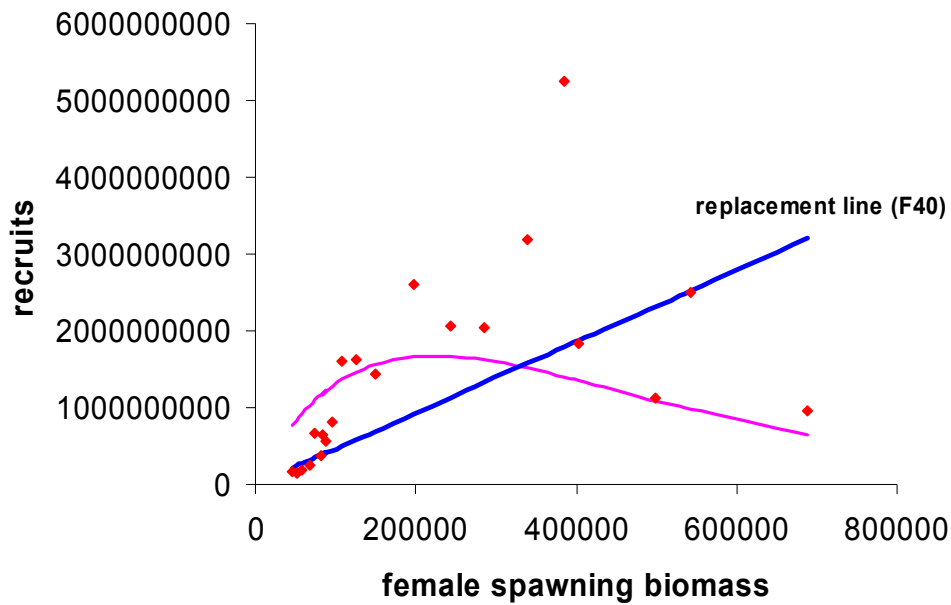


Figure 6.6--Ricker (1958) fit to spawner-recruit data points estimated from the stock assessment model with the F40 replacement line.

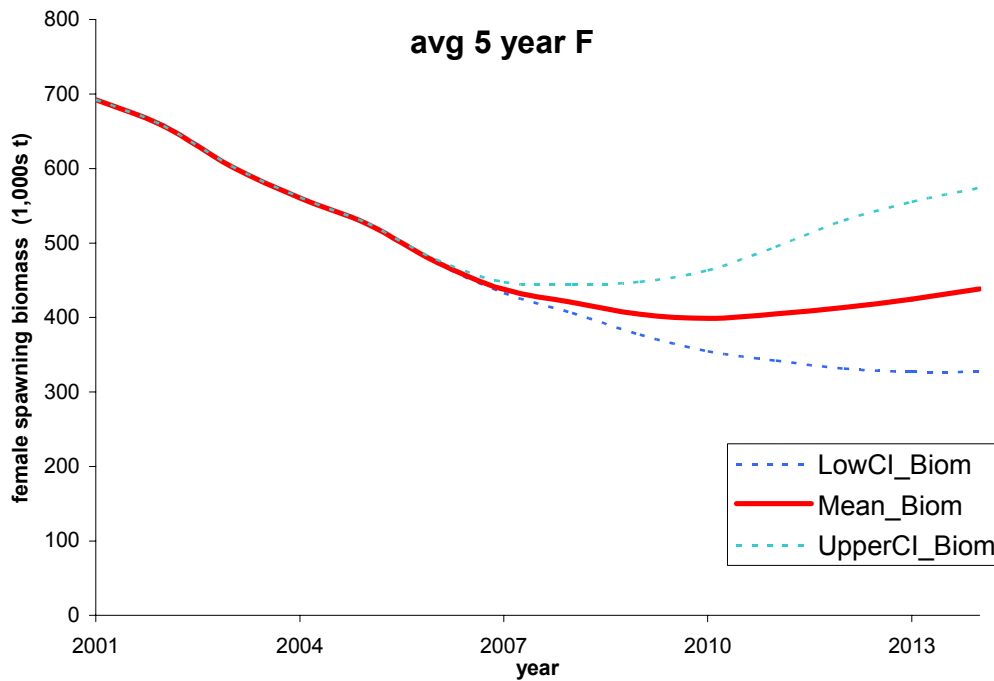


Figure 6.7--Projection of rock sole female spawning biomass (1,000s t) through 2014 with future harvest equal to the average F from 1997-2001